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Recent pollen spectra of highland Guatemala

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Abstract. Data on modern pollen deposition are presented from highland Guatemala and their relation with modern vegetation is examined. Results are based on pollen analysis of sixty-two moss samples collected between 2800 and 4200 m elevation from alpine bunchgrassland, subalpine vegetation and fir forest.

The modern pollen rain data were analyzed by classification (TWINSPAN) and ordination analysis (DCA) and association indices. The degree of over-representation and under-representation of the pollen data with respect to the modern vegetation was established. The fir forest belt (2800–3400 m) shows

highest percentages of *Abies* and Asteraceae, the subalpine forest belt (3400–4000 m) shows highest values of *Juniperus*, *Buddleja* and Poaceae. The alpine bunchgrassland (4000–4200 m) is not characterized by an increased presence of any taxon. *Pinus* (up to 90%), *Alnus* (up to 40%), *Quercus* (up to 7%) and *Hedyosmum* (up to 0.8%) pollen is recovered from all vegetation belts.

Key words. Modern pollen rain, highland Guatemala, Central America, high mountain plant communities.

Resumen. Se presentan los resultados de un estudio de lluvia de polen del altiplano de Guatemala y su relación con la vegetación contemporánea. Estos resultados están basados en un análisis polínico de 62 muestras de musgos colectadas en el zacatonal alpino, la vegetación subalpina y el bosque de abetos.

Los resultados se analizaron con métodos de clasificación (TWINSPAN), ordenación (DCA) e índices de asociación. Se presenta el grado de sobrerrepresentación y de subrepresentación de los datos de polen con respecto a la vegetación actual. El bosque de abetos (2800–3400 m) muestra el porcentaje más

alto de polen de *Abies* y de Asteraceae, el bosque subalpino (3400–4000 m) muestra el valor más alto de polen de *Juniperus*, *Buddleja* y de Poaceae. El zacatonal alpino (4000–4200 m) no se caracteriza por un incremento de algún taxa específico. El polen de *Pinus* (hasta un 90%), *Alnus* (hasta un 40%), *Quercus* (hasta un 7%) y *Hedyosmum* (hasta un 0.8%) está presente en todos los tipos de vegetación.

Palabras claves. Lluvia de polen, altiplano de Guatemala, América Central, comunidades vegetales de alta montaña.

INTRODUCTION

Modern pollen deposition records are used to improve the interpretation of fossil pollen assemblages (Wright Jr, 1967; Hicks, 1986) by establishing qualitative and quantitative relationships between modern pollen rain and the vegetation producing that pollen.

From the Guatemalan highlands first paleoecological studies are in progress (Islebe, *in prep.*). It is clear that an understanding of relationships between modern pollen rain and vegetation is indispensable for accurate interpretation of pollen records from this area. Mountain regions, such as the Guatemalan highlands, present special difficulties for reconstructing Late Quaternary vegetation and climate conditions as in these areas pollen grains are dispersed by winds beyond the vegetation zone from which they originate (Markgraf, 1980).

Studies of the relationship between modern pollen rain and vegetation have been carried out especially in the United States and Europe (e.g. Carroll, 1943; Davis &

Goodlett, 1960; Janssen, 1966, 1967; Lamb, 1984). From neighbouring Mexico four relevant studies can be mentioned, namely Palacios (1977), Lozano-García (1984), Montúfar-López (1985) and Ohngemach & Straka (1983). From South America the studies of Salgado-Labouriau (1978), Grabandt (1980), Bush (1991) and Mancini (1993) can be reported.

The data of the present study come from the upper slopes of the Sierra de los Cuchumatanes (sampled from 2800 to 3800 m) and the Cadena Volcánica sampled from 3000 to 4000 m) (Fig. 1). Three distinct zonal vegetation belts were sampled, (1) the *Abies guatemalensis* Rehder forest, (2) *Pinus hartwegii* Lindl. subalpine forests and (3) the alpine bunchgrassland zone, regionally known as 'zacatonales' (Islebe & Cleef, 1995).

This is the first study dealing with the relationship between modern pollen deposition and vegetation from Guatemala. From the neighbouring Petén lowlands there are some paleoecological studies (e.g. Leyden, 1984, 1987;

Islebe, unpublished), in which reconstructions of the Late Glacial and Holocene vegetation and climate are presented.

SETTING OF THE STUDY AREA

The Sierra de los Cuchumatanes in northwestern Guatemala reaches an altitude of 3800 m. The vegetation zonation is as follows: from 2800 to 3400 m on moist steep slopes *Abies guatemalensis* forests and from 3100 to 3800 m *Juniperus standleyi* Steyermark-*Pinus hartwegii* vegetation. Characteristic Asteraceae of the fir forests are *Ageratina pazcuarensis* (Kunth) K. & R., *Fleischmannia pycnocephaloides* (B. L. Robins.) K. & R., *Sabazia pinetorum* Blake, *Senecio barba-johannis* DC. and *Verbesina apleura* Blake (Islebe, Cleef & Velázquez, 1994).

Characteristic shrub species of these juniper-pine forests are *Aphanactis standleyi* Steyer., *Oxylobus glanduliferus* (Schip. Bip.) Gray, *Holodiscus argenteus* (L.f.) Maxim, *Pernettya prostrata* (Schlecht. & Cham.) Small. and *Mahonia volcania* Standl. & Steyer. Relevant graminoid genera are *Agrostis* L., *Calamagrostis* Adans., *Festuca* L. and *Muehlenbergia* Schreb. The moss species *Thuidium delicatulum* (Hedw.) Mitt. is an important ground covering species.

The Cadena Volcánica (Volcanic Chain) runs through Guatemala parallel to the Pacific coast line and actually is a continuation of the Mexican volcanic ranges. The *Pinus hartwegii* or subalpine forests present similar species compositions as in the above mentioned Cuchumatan subalpine

forests. The alpine bunchgrassland is exclusive to this volcanic mountain range. By phytosociological analysis *sensu* Braun-Blanquet, two communities were recognized, namely a *Lupinus montanus* HBK.-*Calamagrostis vulcanica* Swallen community and a *Luzula racemosa* Desv.-*Arenaria bryoides* Willd. ex Schl. community (Islebe & Cleef, 1995).

The study areas receive 1000–1800 mm rainfall annually and have mean annual temperature of 10°C at 3000 m (Perfil Ambiental, 1987). The rainy season is from May to October, the dry period occurs from November to April, January being the coldest and April the warmest month (Fig. 2).

MATERIAL AND METHODS

Vegetation sampling

The vegetation was studied between 1990 and 1992 following the Braun-Blanquet (1951) approach. Relevés at representative sites were made by estimating the aerial cover of each species. The size of the relevé area was based on minimum area estimates prior to actual sampling (Mueller-Dombois & Ellenberg, 1974). Relevé areas varied between 625 m² for forest types and 30 m² for alpine bunchgrassland. The phytosociological analysis of the relevés was performed by TWINSpan (Hill, 1979b) and the communities mentioned in this study were delineated based on that analysis (Islebe, Velázquez & Cleef, 1995).

FIG. 1. Map of the study area indicating the mountain areas and main pollen sites mentioned in the text.

FIG. 2. Walter diagram of meteorological station Serchil (2940 m). Abbreviations: T-: lowest annual mean temperature; T+: highest annual mean temperature; P-: lowest annual mean precipitation; Py: mean annual precipitation.

Pollen sampling

Several subsamples of moss, mainly consisting of the genera *Hypnum* Hedw., *Pogonatum* P. Beauv., *Thuidium* Bry., *Breutelia* Schimp. and *Leptodontium* Hampe were selected at random for each relevé and stored in plastic bags. Most mosses occurred on soil or low woody vegetation. Adam & Mehringer (1975) suggest that pollen spectra of moss polsters are very representative of the local vegetation. However, there are critics on the use of natural moss cushions as accurate pollen traps as the relationship between pollen rain and vegetation may fluctuate distinctly (Heim, 1971; Ritchie, 1974; Faegri & Iversen, 1989). For practical reasons and in order to have pollen rain samples from every vegetation relevé, moss samples as natural traps were used.

The flowers of several known species were collected during the field work in order to support the determination of the pollen grains present in the different bryophytic samples. Pollen grains and spores were extracted from the moss polsters by standard acetolytic methods (Moore, Webb & Collinson, 1991). For most samples, at least 300 pollen grains of arboreal pollen in addition to other pollen grains and spores were counted at 400 $\times$ magnification. Critical determinations were checked with the recent pollen collection under oil immersion at 1000 $\times$. The pollen sum of the percentage diagram consists of all taxa with the exception of *Eucalyptus*, *Zea* L., fern spores, bryophytes and fungi (Fig. 3). The relationship between recent pollen rain and vegetation can be expressed through an association index (Davis, 1984). This index gives a measure of fidelity for species, which could be indicative of vegetation types (Table 1). In this study the association index 'A' of Davis (1984) is used, which measures if the presence of a pollen type in a surface sample gives an indication of the presence of the plant taxon producing the pollen type in the local vegetation sampled. The formula is as follows:

$$A = B_o / (P_o + P_1 + B_o)$$

where B_o = number of stands in which the pollen type is

present in the surface sample and the taxon is present in the vegetation sample of the stand; P_o = number of stands in which the pollen type is present in the surface sample, but the taxon is absent in the vegetation sample and, P_1 = number of stands in which the plant taxon is present in the vegetation sample but the pollen type is absent in the surface sample. The association index can vary between 0 and 1. If $A = 1$ pollen type and plant taxon always present and $A = 0$ pollen present/plant taxon absent or pollen absent/plant taxon present (Davis, 1984).

The under-representation index U is calculated by the formula

$$U = P_1 / (P_1 + B_o).$$

This index varies from 1.0 for pollen types that are never found when the plant is present, to 0.0 for pollen types that are always present when the plant is present.

The over-representation index O is calculated by the formula

$$O = P_o / (P_o + B_o).$$

This index varies from 1.0 for pollen types that are found when the plant is absent to 0.0 for pollen types that are absent when the plant is absent, too. The pollen percentage diagram was elaborated with the plot program Pollen-Diagram 2.0 (Duivenvoorden, 1991–1992) (Fig. 3).

TWINSPAN (Hill, 1979b) and detrended correspondence analysis (DCA, Hill, 1979a; Hill & Gauch, 1980; Ter Braak, 1988) were performed on the data set in order to elucidate possible underlying patterns. The DCA ordination are expressed in standard deviations of species turnover (Hill, 1979a). The use of multivariate analysis of pollen data is further discussed by Parsons & Prentice (1981) and Birks & Gordon (1985). The TWINSPAN outcome is illustrated in a dendrogram (Fig. 4) and the DCA ordination in a scatter diagram (Fig. 5). Plant nomenclature follows Standley *et al.* (1946–77) and Rzedowski & Rzedowski (1979, 1985, 1991).

RESULTS

Fig. 3 shows the percentages of the recovered pollen taxa in the moss samples from the different vegetation zones. The results will be discussed for individual taxa, based on their growth form.

Trees

The pollen of anemophilous *Pinus* species was found through all the samples. The highest value was reached at 3100 m with 95%. In the treeless alpine bunchgrassland, samples contained nearly 90% *Pinus* pollen. The characteristic pine species of this altitude is *Pinus hartwegii*, although *Pinus ayacahuite* Ehr. and *Pinus montezumae* Lamb., occur in the fir forests at lower elevation. No distinction could be made between these pollen types.

Juniperus pollen was also well distributed over the study area. Like *Pinus* it is a common anemophilous tree in the subalpine forests of the Sierra de los Cuchumatanes. The highest percentage was 85% at an altitude of 3500 m.

FIG. 3. Pollen percentage diagram of the recent pollen rain samples, in order of decreasing altitude with arboreal, shrub and herb taxa as pollen sum.

TABLE 1. Relationship between modern pollen rain and modern vegetation, expressed in index values (for explanation see text).

	Association Index	Under-representation Index	Over-representation Index
Trees			
<i>Pinus</i>	0.97	0	0.03
<i>Juniperus</i>	0.77	0	0.23
<i>Abies</i>	0.19	0	0.81
<i>Alnus</i>	0.23	0	0.77
<i>Buddleja</i>	0.05	0.92	0.81
<i>Quercus</i>	0.13	0	0.85
<i>Hedyosmum</i>	0	0	1
<i>Podocarpus</i>	0	0	1
Shrubs			
<i>Holodiscus</i>	0	0	1
<i>Myrica</i>	0	0	1
Herbs			
<i>Asteraceae</i>	0.89	0	0.11
<i>Poaceae</i>	0.84	0	0.16
<i>Cyperaceae</i>	0.33	0.54	0.45
<i>Arceuthobium</i>	0.65	0	0.35
<i>Caryophyllaceae</i>	0.37	0.63	0
<i>Ericaceae</i>	0.08	0.92	0
<i>Halenia</i>	0.10	0.90	0.2
<i>Cruciferae</i>	0.27	0.6	0.55
<i>Labiatae</i>	0.07	0.89	0.83
<i>Caprifoliaceae</i>	0	1	1
<i>Umbelliferae</i>	0.11	0.87	0.58
<i>Rubiaceae</i>	0.02	0.98	0
<i>Fuchsia</i>	0.09	0.91	0
<i>Dodonaea</i>	0	0	1
<i>Solanaceae</i>	0.14	0.8	0.67
<i>Urticaceae</i>	0	0	1
	$0 \leq A \leq 1$	$0 \leq U \leq 1$	$0 \leq O \leq 1$

Pollen of the anemophilous alder species are found throughout the samples. The most common alder species in the Sierra de los Cuchumatanes and the Cadena Volcánica are *Alnus firmifolia* Fern. and to a lesser extent *Alnus arguta* (Schl.) Spach. and *Alnus jorullensis* HBK. No distinction could be made between these pollen types. The highest percentage (40%) was found at 3260 m in the fir vegetation belt.

Pollen of the entomophilous *Buddleja* Houst. ex L. species did not surpass 1%. From the collected flowers it could be elucidated that it is *Buddleja megalcephala* Donn.

FIG. 4. TWINSpan output representing the different vegetation types.

Smith, a local tree of the subalpine juniper-pine forest. In the actual vegetation this tree covers only small patches, probably because it is thinned out by the local indigenous people.

The pollen of *Abies guatemalensis* was only encountered in small percentages. This is probably due to the destruction of these forests by logging since long ago. In the *Abies* vegetation zone the highest percentage found was 30% at an altitude of 3200 m. Due to the enormous human impact in these forests types, there are only few natural patches with vegetation left. Representation under natural conditions is expected to be distinctly higher.

The pollen of *Quercus* L. was found also throughout the whole set of samples. These pollen grains originate from the mesic forests located between 1500 and 3000 m. The oak pollen present in Fig. 3 belongs probably in most of the cases to *Quercus acatenangensis* Trelease and *Quercus borucasana* Trelease. These oak species are widely distributed at higher elevations and prefer moist conditions. The highest percentage was found at 2800 m with 16%. Percentages up to 5% in samples without oak vegetation are common.

Pollen of anemophilous *Hedyosmum* Sw., also a mesic forest genus and a good pollen producer is found with percentages up to 1% through the samples. Pollen of *Podo-*

FIG. 5. DCA scatter diagram of pollen taxa along the first and second ordination axis.

carpus Pers., another mesic forest genus, was only found in low numbers in two samples. This tree has a patchy distribution and is rare due to logging activities.

Shrubs

The pollen of *Holodiscus argenteus* (1%) was found in samples collected from the subalpine juniper-pine forest. In these forests this species is a characteristic understorey shrub.

The pollen of *Myrica* L. (1%) was found in all vegetation types. *Myrica* occurs up to 2900 m and especially at disturbed sites in association with *Dodonaea viscosa* (L.) Jacq.

The pollen of entomophilous Caprifoliaceae was found in one sample from the subalpine vegetation belt (<1%). Species (e.g. *Symphoricarpos microphyllus* HBK. and *Viburnum euriphylla* Benth.) representing these family occur in the humid fir forests.

Herbs

Pollen of the Poaceae had its highest value (14%) in the alpine bunchgrassland, where *Calamagrostis vulcanica*, *Agrostis tolucensis* HBK. and *Festuca tolucensis* HBK. species dominate the ground cover. Graminous taxa are equally well represented in the subalpine pine forests, where apart from the above mentioned species *Muehlenbergia macroura* (HBK.) Hitchc. and *Muehlenbergia quadridentata* (HBK.) Kunth also occur.

Asteraceae pollen had its maximum (50%) in the fir vegetation zone (Fig. 3). In this zone Asteraceae of the genera *Archibaccharis* Heering, *Ageratina* O. Hoffm., *Eupatorium* L., *Fleischmannia* Sch. Bip., *Roldana* La Llave, *Senecio* L. and *Verbesina* L. occur abundantly. Asteraceae pollen in the subalpine zone is probably mostly from the entomophilous *Oxylobus glanduliferus*. Some Asteraceae like *Helenium integrifolium* (HBK.) Benth & Hook and

Werneria nubigena Kunth are favoured by the continuous sheep grazing and cover many seminatural meadows.

Pollen of *Arceuthobium globosum* Hawksworth & Wiens (Loranthaceae) was found in nearly all the samples with more than 40% in one sample from the fir forest zone. *A. globosum* is a hemiparasite on pines, that has been found in the Central Mexican pollen rain (Ohngemach & Straka, 1983). In the Cuchumatán study area nearly 80% of all pines were infected with *Arceuthobium* (Islebe, unpublished).

Pollen of Caryophyllaceae, probably of the genus *Arenaria* L., was rarely found. In the subalpine zone it once reached nearly 10%. The entomophilous cushion plant is most common in the study area.

Ericaceous pollen, probably *Pernettya* Gaudich. and *Vaccinium* L., was found with low percentages (1%) in the subalpine and fir forest zone.

Pollen of *Halenia* (Gentianaceae) was found in all three vegetation types, although the plant does not occur in the alpine bunchgrassland. At 2800 m 10% of *Halenia* Borekh. was found, but this was a disturbed site, which is preferred by *Halenia decumbens*.

Pollen of the entomophilous Cruciferae (up to 1%) were also found in all three vegetation types. Most of the pollen probably belongs to *Draba* L. and *Romanschulzia* Schulz.

Pollen of the entomophilous Lamiaceae (1%) was found in the subalpine and fir forest zone. In the fir forest zone several *Salvia* L. species are common, but their pollen is difficult to distinguish.

Pollen of Apiaceae was only found in one sample (<1%), it probably belongs to the genus *Eryngium*. L. *Eryngium* species in the subalpine belt of the study area are characteristic of disturbed vegetation, overgrazed by sheep.

Pollen of *Fuchsia* L. was exclusively found in samples from the fir vegetation belt. In these forest *Fuchsia microphylla* HBK. is a characteristic ground cover. Pollen of the entomophilous *Dodonaea* was found in some samples up to 0.5%. *Dodonaea* is a disturbance-indicator and in patches with open vegetation associated with *Myrica*.

Pollen of Solanaceae, belonging to *Cestrum* L. and *Solanum* L. species, was only found in low percentages (1%) and occurred both in the subalpine as well as fir vegetation belt.

Pollen of corn (*Zea*) was encountered in several samples with low percentages (1%). Corn fields are found up to 3000 m in the Sierra de los Cuchumatanes and the Cadena Volcánica.

Pollen of planted *Eucalyptus* (<1%) trees was found in two samples, one in the alpine and the other in the fir zone.

Cyperaceae pollen was found in all samples. In the studied area Cyperaceae grow in wet or humid places.

Spores of the fern *Asplenium* L. were recognized in all samples (up to 10%). Other fern spores were classified as monolete psilate, monolete verrucate, trilete psilate and verrucate.

Association indices

Two species of trees had a high calculated association index: *Pinus* (0.97) and *Juniperus* (0.77) (Table 1). *Pinus*, *Juniperus*, Asteraceae, Poaceae, *Arceuthobium* represent taxa for which the pollen type and the plant taxon tend to co-occur in a sampled stand and for which $A > 0.50$. These are good indicator species for a given forest vegetation. However, the pollen percentages of *Pinus* are high even in samples from sites where pine trees are absent, and the high scores for the association index may result from the ubiquity of the pollen type and associated plants rather than a close relationship between plant and pollen occurrence.

Taxa which were found in the pollen samples but were absent in the local vegetation were *Hedyosmum*, *Podocarpus* and *Myrica*. Pollen of these trees/shrubs disperse beyond the limits of the vegetation type concerned and is consequently over-represented.

Some pollen taxa are absent when the corresponding plant taxa are present. These include under-represented taxa like *Buddleja*, *Holodiscus* and Ericaceae. Pollen taxa with high over-representation scores must have well dispersed pollen, because the source plants are absent in the stand where the pollen sample was collected. This does not mean that those taxa have a high pollen production.

Multivariate analysis of the recent pollen rain data by means of classification and ordination

The TWINSpan outcome is summarized in a dendrogram (Fig. 4), showing a clear segregation of the juniper-pine and fir forest.

Individual species ordination by DCA is presented in Fig. 5. Ordination axes can be best identified when the environmental condition of characteristic taxa are known (Whittaker, 1967, 1973). The principle axes of a DCA ordination could then be interpreted (Gauch, 1982; Birks & Gordon, 1985). The first (horizontal) axes of the DCA ordination of the modern pollen data runs from a group of pollen taxa indicating humid conditions at the positive end to pollen taxa characteristic of more dry conditions at the negative end. The pollen taxa indicating humid conditions are *Abies*, Asteraceae, Cruciferae, *Alnus* and *Hedyosmum*.

Pinus gives unclear ecological information, because pine species occur in mesic as well as dry forests, but the pollen type is considered as one single taxon. The pollen taxa indicating drier conditions are *Juniperus*, Poaceae, *Halenia* and *Myrica*. The change from dry to humid habitats suggests that the first axis represents a humidity gradient. In this study the second axis could not be related to a specific environmental variable.

DISCUSSION AND CONCLUSION

The pollen grains encountered in the moss samples provide the first data on modern pollen deposition in highland Guatemala and form a basis, for the interpretation of palynological studies in progress.

The results can be best compared with data from similar vegetation types in the region, and these are provided by the work of Ohngemach & Straka (1983). In their modern pollen-vegetation studies they found similar trends as presented in this paper. The arboreal pollen taxa that seem to be the most over-represented are *Pinus*, *Alnus* and partly *Quercus*. A similar trend is evidenced for *Abies* pollen grains, which can be found in different vegetation types, but generally is under-represented. Pollen of Poaceae, Asteraceae and sometimes *Arceuthobium* is well distributed over different vegetation types in the Mexican highlands (Ohngemach & Straka, 1983).

Using the modern relationship between pollen deposition and vegetation does not imply that we expect that forests documented by fossil pollen records were always identical to the actual ones. Multivariate analysis have shown certain characteristic features of the different plant communities, which are recognizable in the actual Guatemalan high mountain vegetation. However, the alpine bunchgrassland could not be distinguished separately (Fig. 4), although the highest Poaceae percentages were found in that zonal vegetation type. This is probably due to the small area occupied by this vegetation type in Guatemala, the exposure of the mountain tops and the constant deposition of pine pollen, a general problem already outlined by Markgraf (1980) in European mountain zones. Ohngemach & Straka (1983) found a similar pattern in the Mexican alpine vegetation, with relative higher percentages of Graminae, but still a clear overrepresentation of *Pinus*.

The altitudinal distribution of the modern pollen rain of *Abies*, *Buddleja* and *Juniperus* correspond well with the altitudinal limits of the vegetation belts concerned.

The samples from the pine vegetation belt with *Pinus* percentages below 15%, are considered as examples that demonstrate human destruction of the natural vegetation. It should be taken into consideration that pollen representation in the moss samples is influenced by the local/regional production, transport and preservation. As expected, pollen from entomophilous taxa are under-represented or absent in the pollen rain recorded by moss samples.

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TABLE 2. Elevation, location, and modern vegetation type of pollen rain samples. The number in parentheses is the pollen sum.

1.	4200 m, Tajumulco volcano, alpine bunchgrassland (379)
2.	4000 m, Tacaná volcano, alpine bunchgrassland (446)
3.	3950 m, Tacaná volcano, alpine bunchgrassland (398)
4.	3900 m, Tajumulco volcano, alpine bunchgrassland (504)
5.	3850 m, Tajumulco volcano, alpine bunchgrassland (367)
6.	3660 m, Sierra de los Cuchumatanes, juniper-pine forest (654)
7.	3650 m, Sierra de los Cuchumatanes, juniper-pine forest (438)
8.	3645 m, Sierra de los Cuchumatanes, pine forest (332)
9.	3630 m, Sierra de los Cuchumatanes, juniper forest (451)
10.	3610 m, Sierra de los Cuchumatanes, juniper-pine forest (374)
11.	3605 m, Sierra de los Cuchumatanes, pine forest (351)
12.	3600 m, Sierra de los Cuchumatanes, pine forest (500)
13.	3590 m, Sierra de los Cuchumatanes, pine forest (318)
14.	3585 m, Sierra de los Cuchumatanes, juniper forest (582)
15.	3580 m, Sierra de los Cuchumatanes, juniper-pine forest (501)
16.	3575 m, Sierra de los Cuchumatanes, juniper forest (361)
17.	3570 m, Sierra de los Cuchumatanes, juniper-pine forest (506)
18.	3560 m, Sierra de los Cuchumatanes, juniper forest (542)
19.	3550 m, Sierra de los Cuchumatanes, juniper-pine forest (643)
20.	3540 m, Sierra de los Cuchumatanes, juniper-pine forest (111)
21.	3520 m, Sierra de los Cuchumatanes, juniper-pine forest (366)
22.	3510 m, Sierra de los Cuchumatanes, juniper-pine forest (340)
23.	3500 m, Sierra de los Cuchumatanes, juniper-pine forest (338)
24.	3495 m, Sierra de los Cuchumatanes, juniper forest (376)
25.	3490 m, Sierra de los Cuchumatanes, juniper-pine forest (215)
26.	3490 m, Sierra de los Cuchumatanes, juniper-pine forest (309)
27.	3485 m, Sierra de los Cuchumatanes, pine forest (438)
28.	3480 m, Sierra de los Cuchumatanes, juniper-pine forest (442)
29.	3470 m, Sierra de los Cuchumatanes, juniper forest (516)
30.	3460 m, Sierra de los Cuchumatanes, juniper-pine forest (457)
31.	3450 m, Sierra de los Cuchumatanes, juniper-pine forest (340)
32.	3440 m, Sierra de los Cuchumatanes, juniper forest (267)
33.	3430 m, Sierra de los Cuchumatanes, juniper-pine forest (429)
34.	3420 m, Sierra de los Cuchumatanes, pine forest (341)
35.	3370 m, Sierra de los Cuchumatanes, pine-fir forest (416)
36.	3330 m, Sierra de los Cuchumatanes, pine-fir-alder forest (466)
37.	3310 m, Sierra de los Cuchumatanes, pine-fir forest (360)
38.	3300 m, Tajumulco volcano, pine-fir forest (578)
39.	3295 m, Sierra de los Cuchumatanes, pine-fir forest (430)
40.	3285 m, Sierra de los Cuchumatanes, pine-fir forest (415)
41.	3280 m, Sierra de los Cuchumatanes, fir forest (404)
42.	3260 m, Sierra de los Cuchumatanes, fir forest (528)
43.	3255 m, Sierra de los Cuchumatanes, fir-alder forest (564)
44.	3250 m, Sierra de los Cuchumatanes, juniper forest (343)
45.	3245 m, Sierra de los Cuchumatanes, fir forest (374)
46.	3240 m, Sierra de los Cuchumatanes, fir forest (383)
47.	3230 m, Sierra de los Cuchumatanes, fir forest (397)
48.	3220 m, Tajumulco volcano, fir forest (374)
49.	3210 m, Tajumulco volcano, fir forest (399)
50.	3200 m, Sierra de los Cuchumatanes, fir forest (641)
51.	3160 m, Sierra de los Cuchumatanes, pine forest (466)
52.	3150 m, Sierra de los Cuchumatanes, fir-alder forest (510)
53.	3140 m, Sierra de los Cuchumatanes, fir-alder forest (168)
54.	3130 m, Sierra de los Cuchumatanes, fir-alder forest (728)
55.	3100 m, Santa María volcano, fir-cypres forest (508)
56.	3090 m, Acatenango volcano, alder forest (331)
57.	3000 m, Santa Maria volcano, fir-cypres-pine forest (443)
58.	2980 m, Sierra de los Cuchumatanes, cypres forest (457)
59.	2900 m, Sierra de los Cuchumatanes, pine-alder forest (369)
60.	2830 m, Sierra de los Cuchumatanes, pine-alder forest (398)
61.	2810 m, Santa María volcano, pine-alder forest (346)
62.	2800 m, Sierra de los Cuchumatanes, alder forest (183)

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